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(54) FREQUENCY-BASED WEB STEERING IN PRINTING SYSTEMS

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(22) Filed: **Jul. 2, 2013**

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(51) **Int. Cl.**

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B41J 29/38	(2006.01)
B65H 20/00	(2006.01)
B41J 15/04	(2006.01)
B65H 23/032	(2006.01)

(52) **U.S. Cl.**

CPC ***B65H 20/00*** (2013.01); ***B41J 15/046*** (2013.01); ***B65H 23/032*** (2013.01); ***B65H 23/02*** (2013.01)

(58) **Field of Classification Search**

CPC B41J 15/046

See application file for complete search history.

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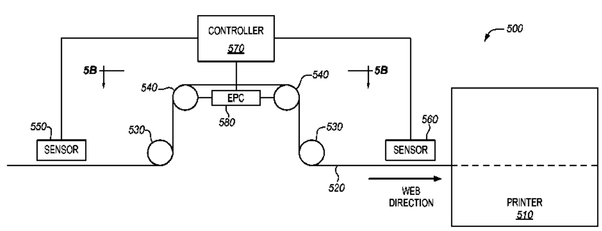
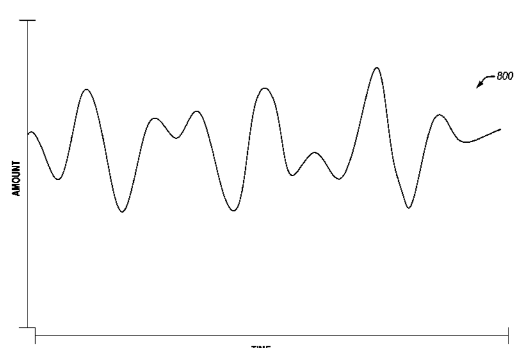
(57) ABSTRACT

Systems and methods are provided for predictively compensating for frequency-based shifts of the position of a web of print media in a continuous-forms printer. The system comprises a sensor and a controller. The sensor is able to detect lateral shifts of the web of print media traveling through the continuous-forms printer. The controller is able to identify a frequency of the lateral shifts of the web, and to steer the web based on the frequency.

24 Claims, 9 Drawing Sheets





LATERAL STEERING OVER TIME (PREDICTIVE)

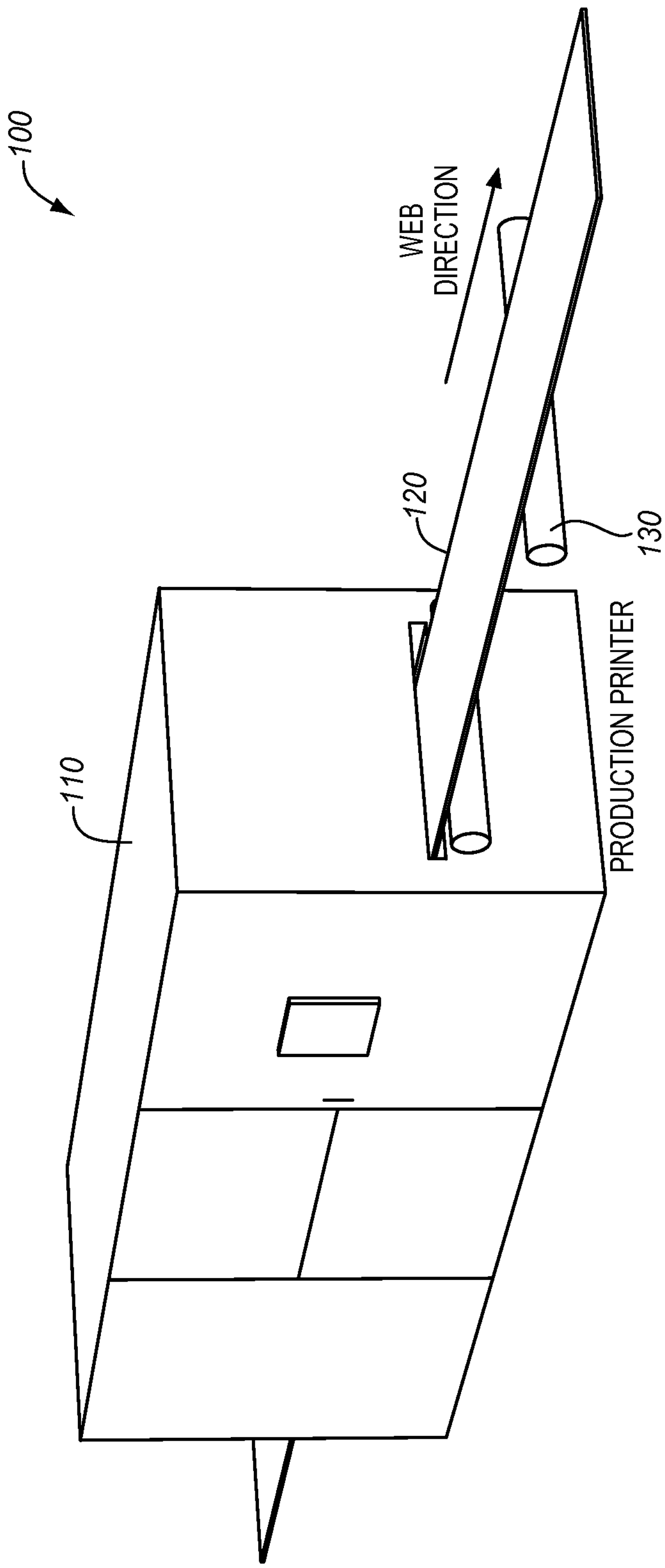
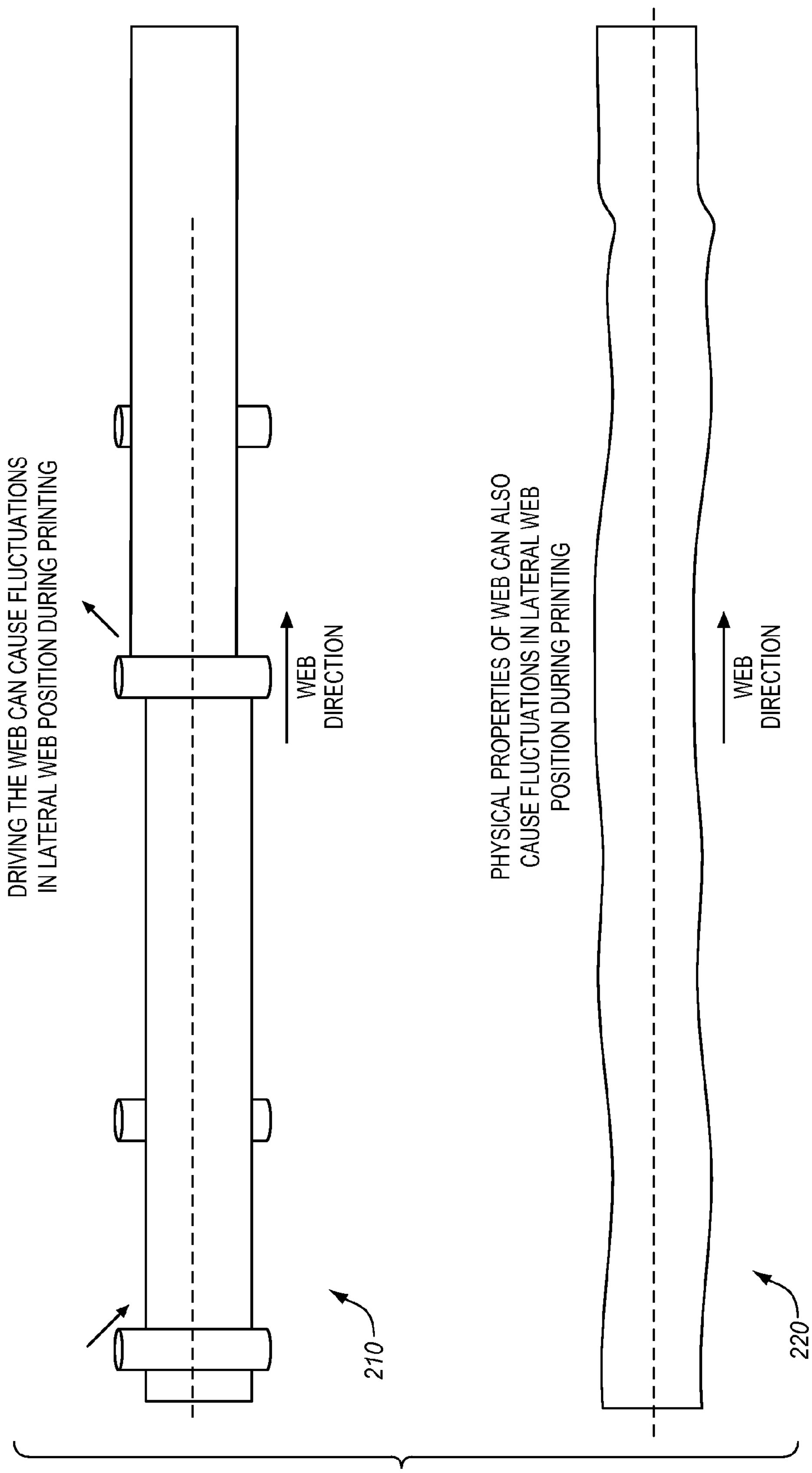


FIG. 1

FIG. 2


DRIVING THE WEB CAN CAUSE FLUCTUATIONS
IN LATERAL WEB POSITION DURING PRINTING
WEB
DIRECTION
210
PHYSICAL PROPERTIES OF WEB CAN ALSO
CAUSE FLUCTUATIONS IN LATERAL WEB
POSITION DURING PRINTING
WEB
DIRECTION
220

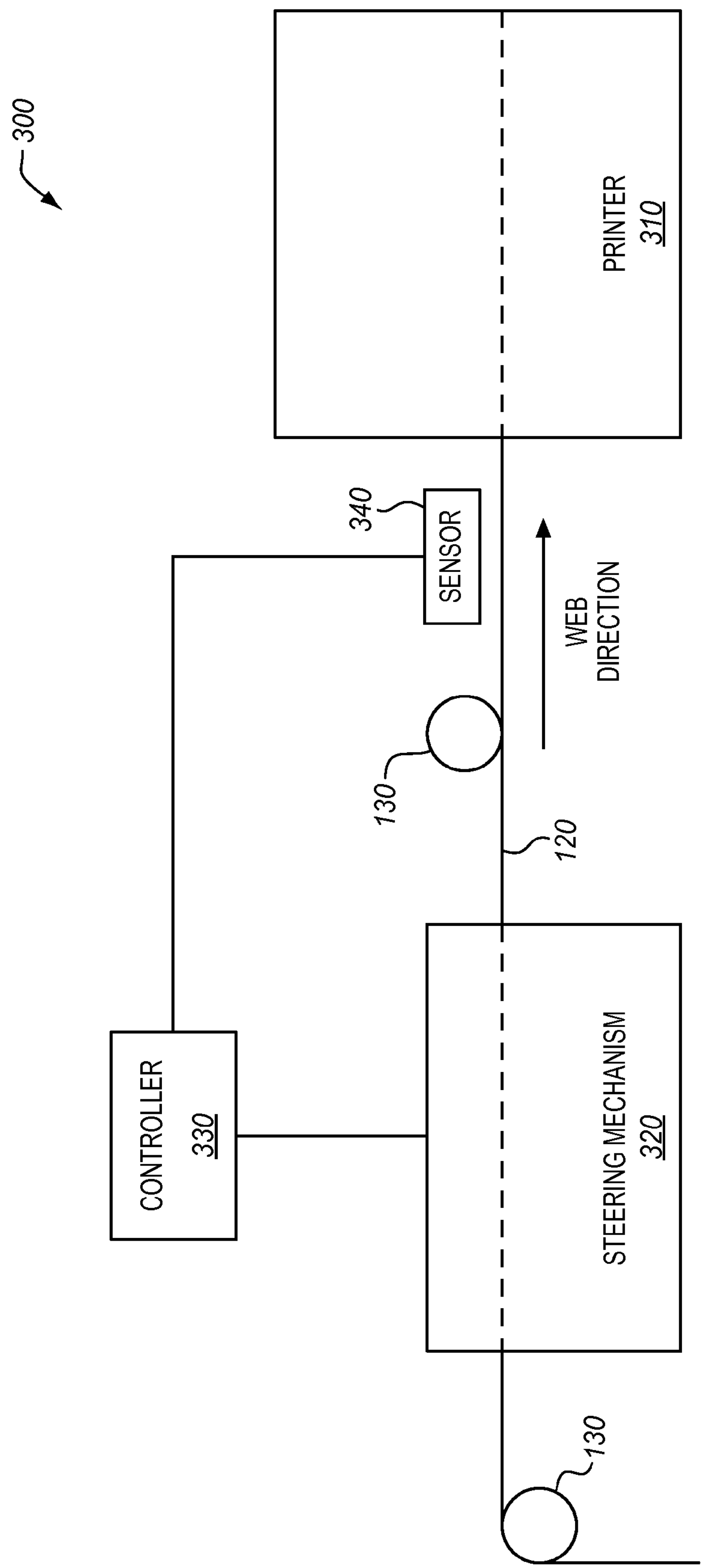
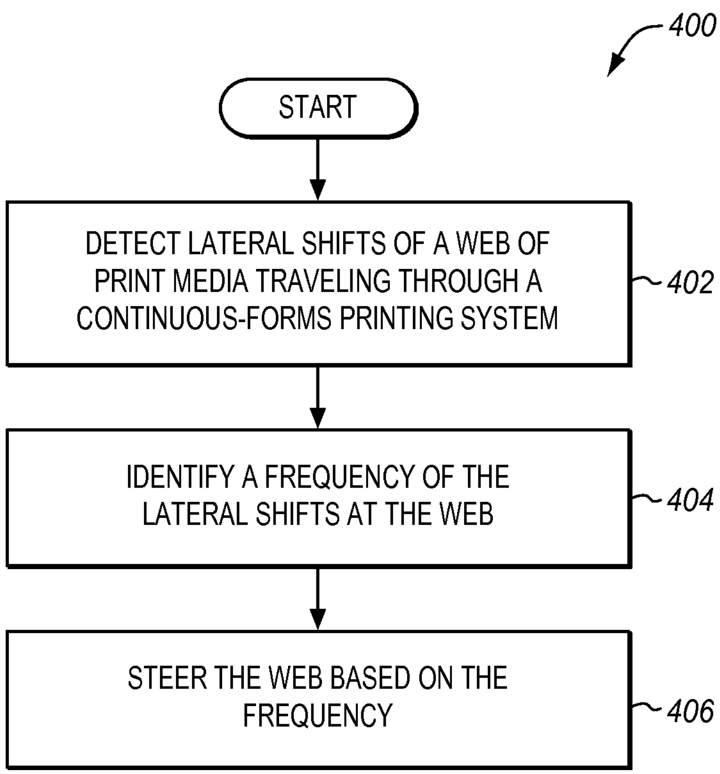

300
PRINTER
310
SENSOR
340
WEB
DIRECTION
130
120
STEERING MECHANISM
320
CONTROLLER
330
130

FIG. 3

FIG. 4


400
START
DETECT LATERAL SHIFTS OF A WEB OF PRINT MEDIA TRAVELING THROUGH A CONTINUOUS-FORMS PRINTING SYSTEM
402
IDENTIFY A FREQUENCY OF THE LATERAL SHIFTS AT THE WEB
404
STEER THE WEB BASED ON THE FREQUENCY
406

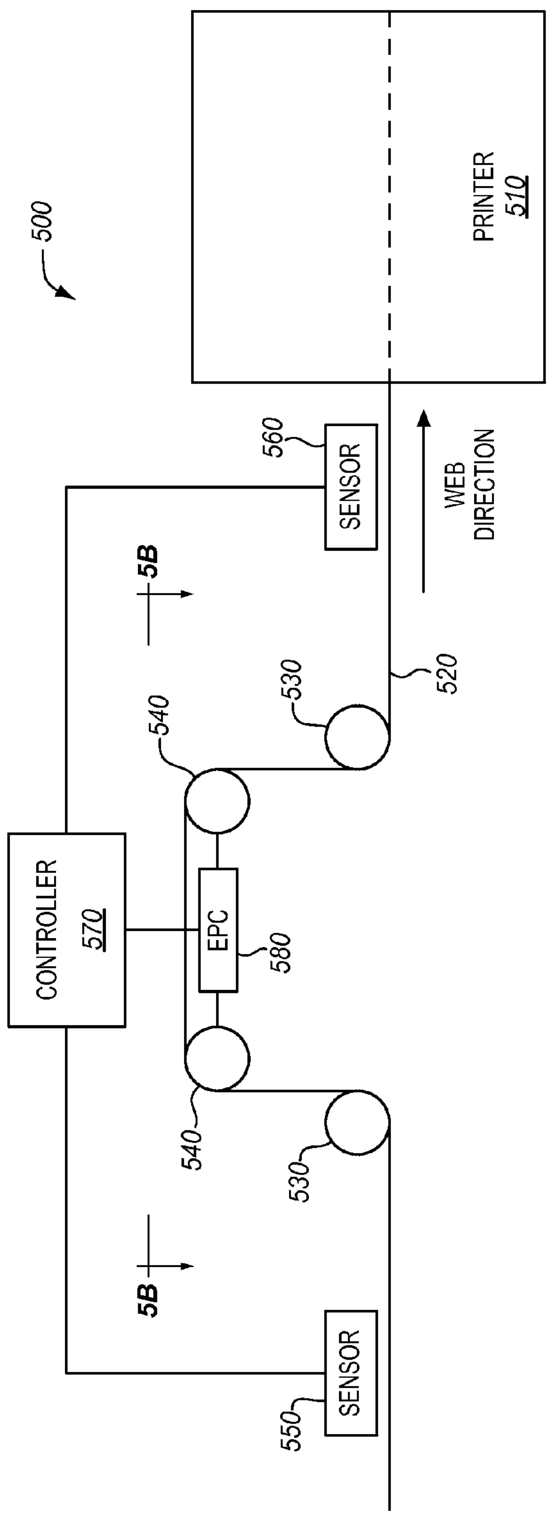

500
PRINTER
510
SENSOR
560
WEB
DIRECTION
5B
520
530
540
CONTROLLER
570
EPC
580
540
530
5B
SENSOR
550

FIG. 5A

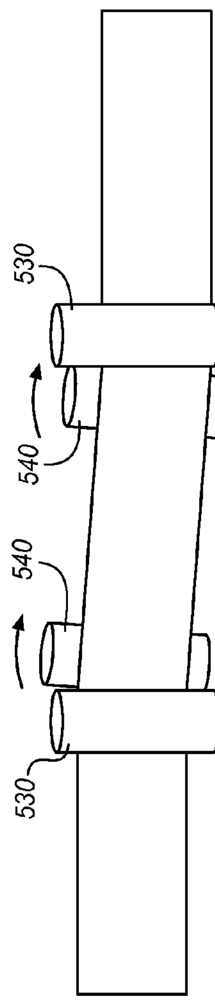
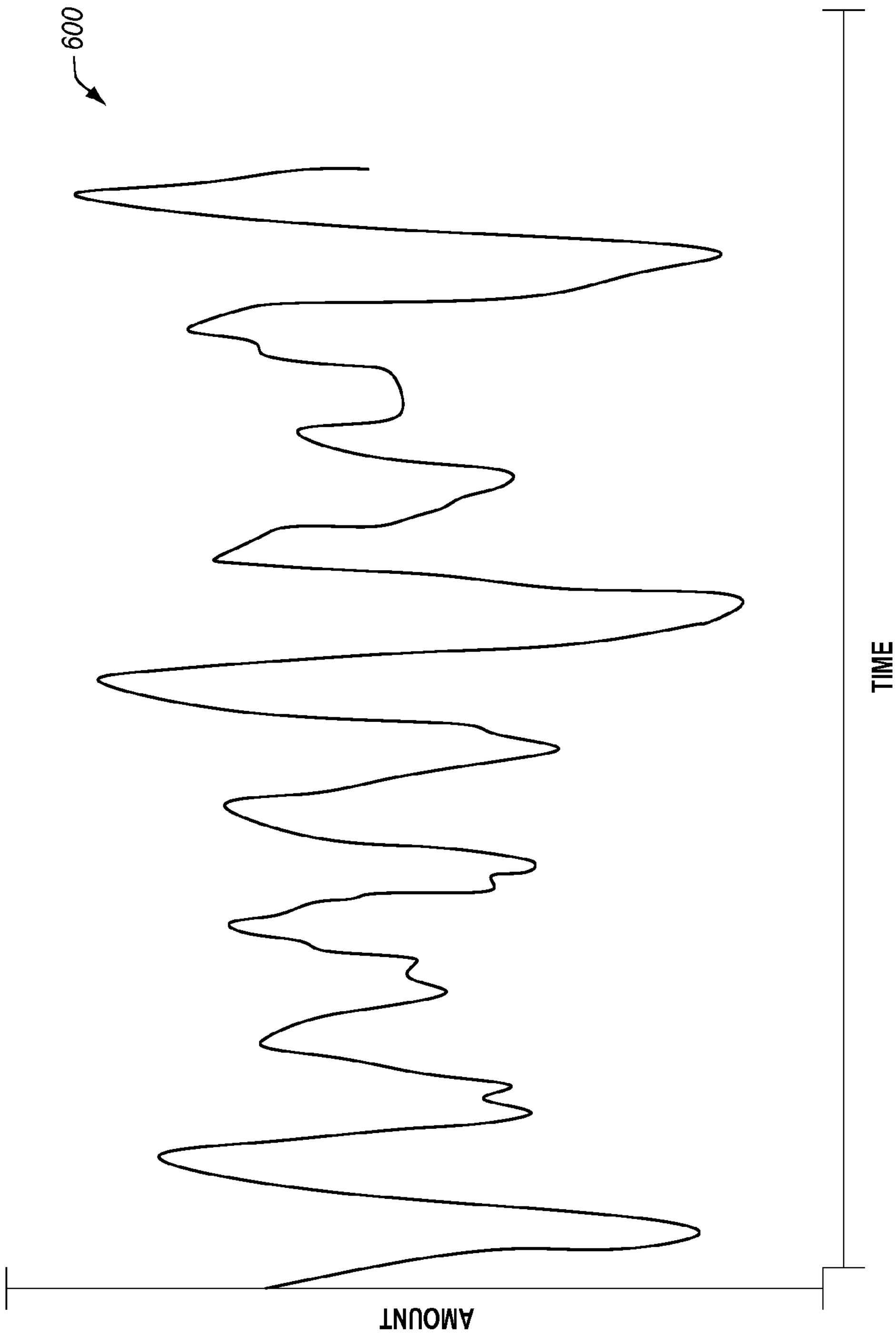

530
540
540
530

FIG. 5B



LATERAL SHIFTS OVER TIME

FIG. 6

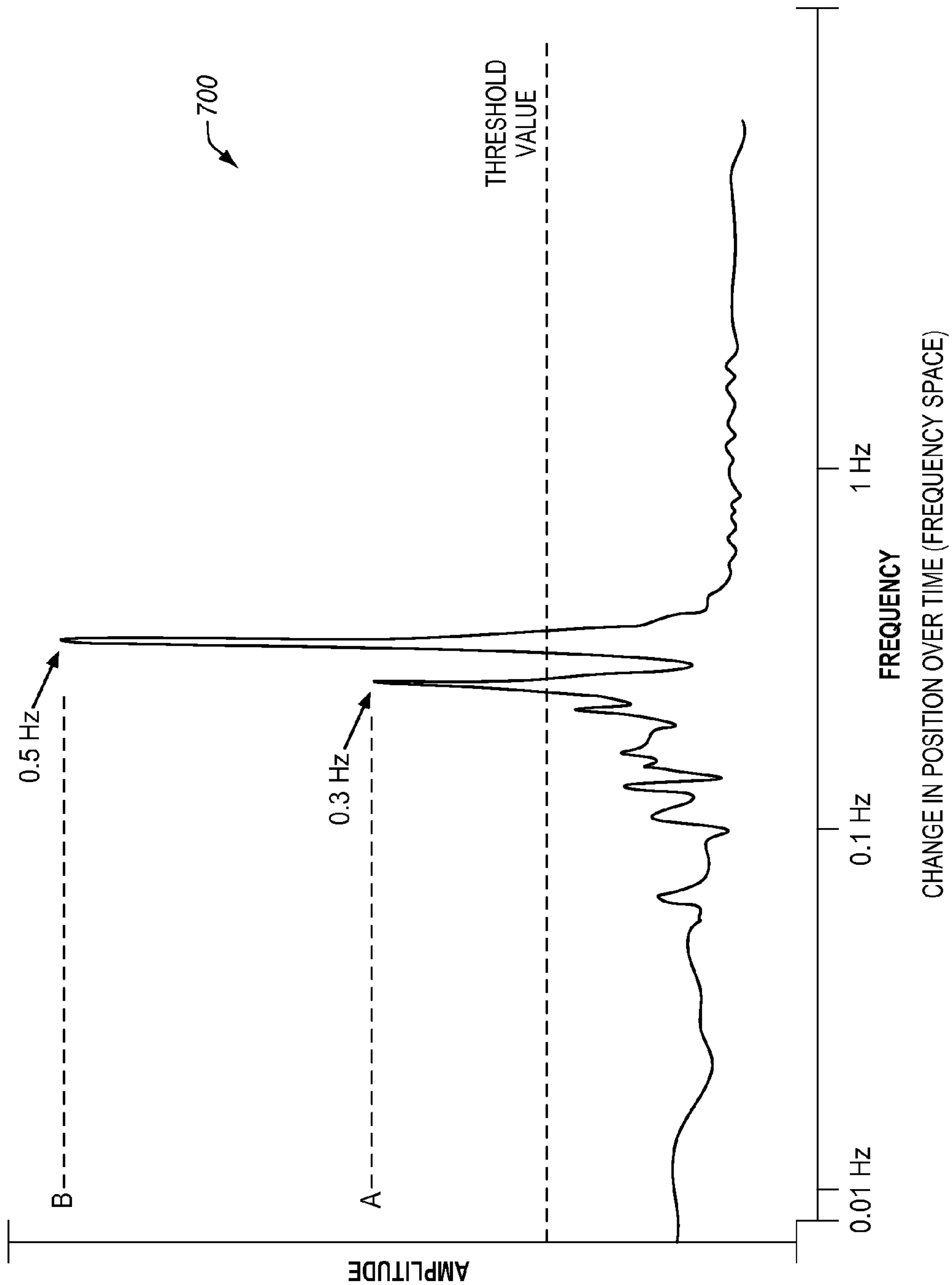
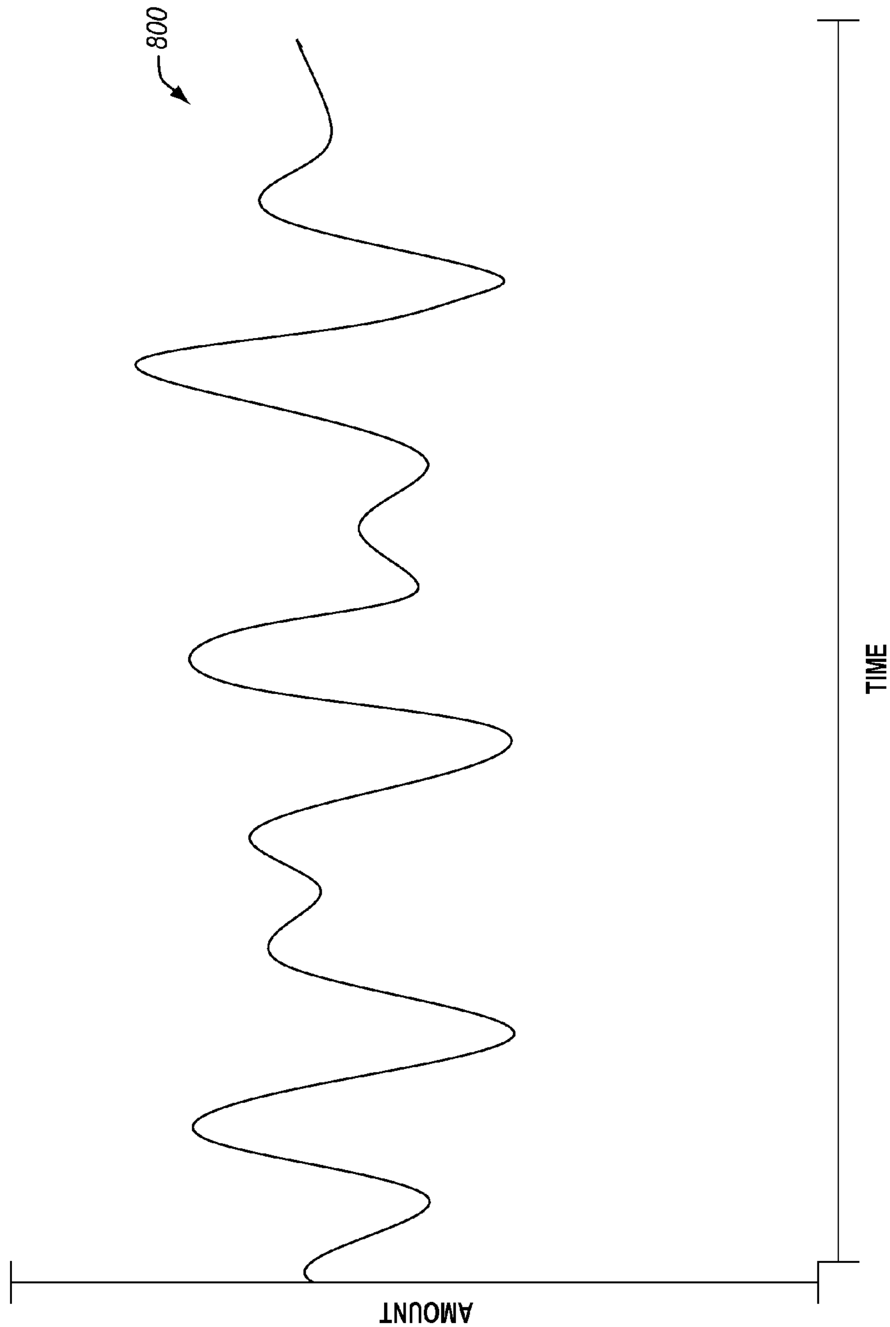

700
THRESHOLD VALUE
0.5 Hz
0.3 Hz
B
A
AMPLITUDE
0.01 Hz
0.1 Hz
1 Hz
FREQUENCY
CHANGE IN POSITION OVER TIME (FREQUENCY SPACE)

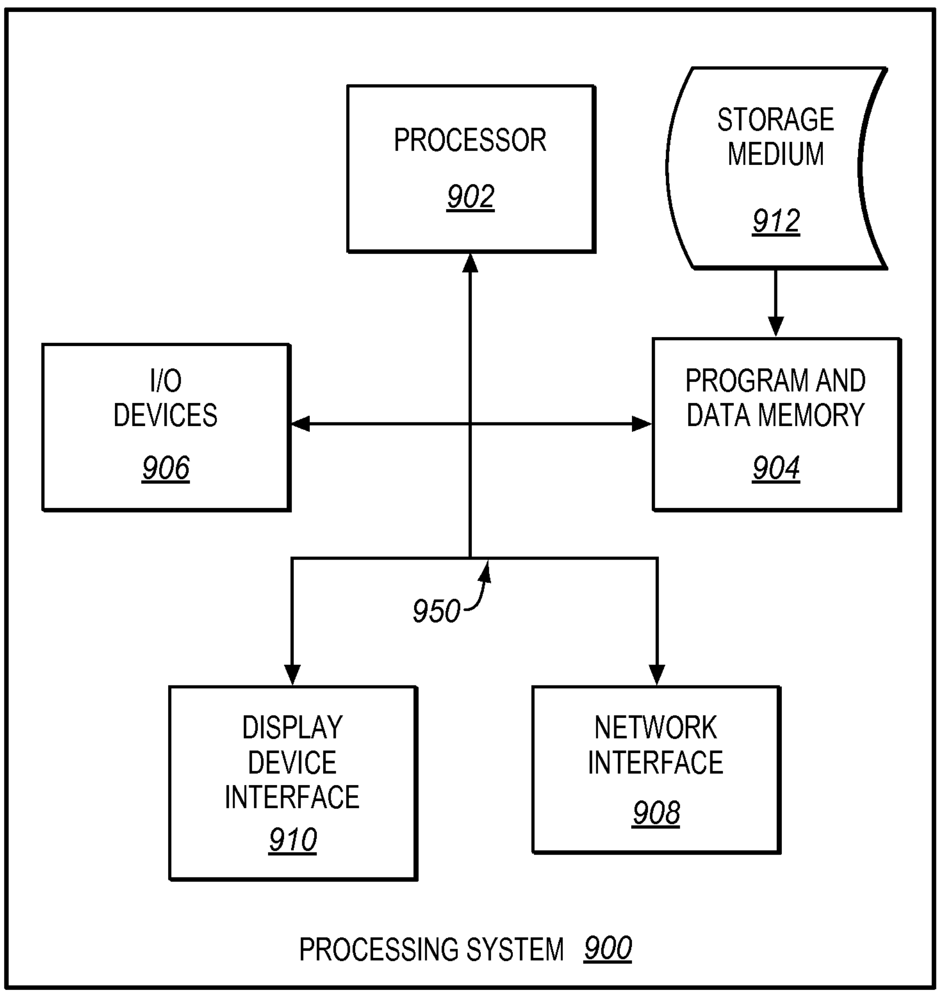
FIG. 7



LATERAL STEERING OVER TIME (PREDICTIVE)

FIG. 8

FIG. 9


PROCESSOR
902
STORAGE
MEDIUM
912
I/O
DEVICES
906
PROGRAM AND
DATA MEMORY
904
950
DISPLAY
DEVICE
INTERFACE
910
NETWORK
INTERFACE
908
PROCESSING SYSTEM 900

FREQUENCY-BASED WEB STEERING IN PRINTING SYSTEMS

FIELD OF THE INVENTION

The invention relates to the field of printing systems, and in particular, to aligning webs of media for continuous-forms printing systems.

BACKGROUND

Entities with substantial printing demands typically use a production printer. A production printer is a high-speed printer used for volume printing (e.g., one hundred pages per minute or more). Production printers include continuous-forms printers that print on a web of print media stored on a large roll.

A production printer typically includes a localized print controller that controls the overall operation of the printing system, and a print engine (sometimes referred to as an "imaging engine" or a "marking engine"). The print engine includes one or more printhead assemblies, with each assembly including a printhead controller and a printhead (or array of printheads). An individual printhead includes multiple (e.g., hundreds of) tiny nozzles that are operable to discharge ink as controlled by the printhead controller. A printhead array is formed from multiple printheads that are spaced in series across the width of the web of print media.

While the printer prints, the web is quickly passed underneath the nozzles, which discharge ink onto the web at intervals to form pixels. In order to ensure that the web is consistently positioned underneath the nozzles, steering systems can be used to align the web laterally with respect to its direction of travel. For example, these steering systems can be calibrated when the printer is first installed. However, even when the web is aligned, fluctuations in the physical properties of the web (e.g., small micron-level variations along the edge of the web, lateral tension variation along the web, orientation of the fibers in the web, etc.) can cause the web to experience lateral shifts during printing. This means that printed output for a job can shift back and forth laterally across the pages of a document. Even though the individual shifts can be small (e.g., on the order of microns), the shifts can reduce print quality. For example, when multiple printheads are used by a printer to form a mixed color pixel, a small fluctuation in web position can cause one printhead to mark the correct physical location, while another printhead marks the wrong physical location. This distorts the final color of the pixel in the printed job.

SUMMARY

Embodiments described herein can analyze lateral shifts at a web of print media over time. Based on this data, the shifts can be modeled in the frequency domain. The web can then be predictively steered laterally to account for the frequency (or frequencies) at which the web naturally shifts during printing.

One embodiment is a system used to predictively compensate for frequency-based shifts of the position of a web of print media in a continuous-forms printer. The system comprises a sensor and a controller. The sensor is able to detect lateral shifts of the web of print media traveling through the continuous-forms printer. The controller is able to identify a frequency of the lateral shifts of the web, and to steer the web based on the frequency.

Other exemplary embodiments (e.g., methods and computer-readable media relating to the foregoing embodiments) may be described below.

DESCRIPTION OF THE DRAWINGS

Some embodiments of the present invention are now described, by way of example only, and with reference to the accompanying drawings. The same reference number represents the same element or the same type of element on all drawings.

FIG. **1** illustrates an exemplary continuous-forms printing system.

FIG. **2** illustrates how a web of print media can oscillate laterally within the printing system of FIG. **1** during printing.

FIG. **3** is a block diagram illustrating an exemplary printing system that accounts for lateral shifts at a web of print media.

FIG. **4** is a flowchart illustrating an exemplary method of accounting for lateral shifts at a web of print media.

FIGS. **5**A-B are block diagrams illustrating a further exemplary printing system that accounts for lateral shifts at a web of print media.

FIG. **6** is a graph illustrating exemplary measured lateral shifts at a web of print media.

FIG. **7** is a graph illustrating an exemplary frequency domain analysis of the lateral shifts shown in FIG. **6**.

FIG. **8** is a graph illustrating an exemplary waveform generated to compensate for predicted future lateral shifts at a web of print media.

FIG. **9** illustrates a processing system operable to execute a computer readable medium embodying programmed instructions to perform desired functions in an exemplary embodiment.

DETAILED DESCRIPTION

The figures and the following description illustrate specific exemplary embodiments of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within the scope of the invention. Furthermore, any examples described herein are intended to aid in understanding the principles of the invention, and are to be construed as being without limitation to such specifically recited examples and conditions. As a result, the invention is not limited to the specific embodiments or examples described below, but by the claims and their equivalents.

FIG. **1** illustrates an exemplary continuous-forms printing system **100**. Printing system **100** includes production printer **110**, which is operable to apply ink onto a web **120** of continuous-form print media (e.g., paper). As used herein, the word "ink" is used to refer to any suitable marking fluid that can be applied by a printer (e.g., aqueous inks, oil-based paints, etc.). Printer **110** may comprise an inkjet printer that applies colored inks, such as Cyan (C), Magenta (M), Yellow (Y), and Key (K) black inks. One or more rollers **130** position web **120** as it travels through printing system **100**.

FIG. **2** illustrates how a web of print media can shift laterally within the exemplary printing system of FIG. **1** during printing. For example, FIG. **2** at element **210** illustrates that rollers can impart lateral shifts to a web of print media. As used herein, a lateral shift is a change in position or tension that is within the plane of the web and orthogonal to the direction of travel of the web (i.e., orthogonal to the length of the web, and parallel to the width of the web).

As shown in element **210**, before traveling through a roller the lateral position of the web (with respect to the web's direction of travel) is above the dashed reference line. After traveling through the roller, it is below the reference line. Furthermore, the degree of lateral shifting imparted by the printing system itself can oscillate in amplitude and direction while the printing system is operating. In short, the very act of driving the web can cause the web to laterally oscillate back and forth at a natural frequency. No static adjustments can compensate for these oscillating lateral shifts that occur during printing.

FIG. **2** at element **220** shows that the web itself can also contribute to lateral fluctuations. Element **220** shows that a web may have an uneven edge. For example, some webs of print media are initially cut with a blade. When a long cut is being made, the blade itself can oscillate laterally back and forth at a certain frequency by very small amounts (e.g., a few microns). This in turn imparts an uneven edge to the web. Since many printheads maintain the same absolute position while printing, the distance of printed marks relative to the edge of the paper will vary as the edge of the paper itself varies, which can reduce print quality.

FIG. **3** is a block diagram illustrating an exemplary printing system **300** used to address the problems with shifting webs discussed above. Printing system **300** includes printer **310**, which is capable of printing onto web **120**, as well as rollers **130** which vertically position and tension web **120** during printing. Printing system **300** has been enhanced to predictively compensate for lateral shifts of web **120** during printing. Specifically, printing system **300** includes a steering mechanism **320**, a controller **330**, and a sensor **340** that can operate together to predictively adjust for lateral shifts of the web. Lateral shifts in web **120** can comprise changes in side-to-side tension or lateral position of the web during printing.

Sensor **340** comprises any system, component, or device operable to detect shifts in web **120**. For example, sensor **340** can comprise a laser, pneumatic, photoelectric, ultrasonic, infrared, optical, or any other suitable type of sensing device. In one embodiment, sensor **340** comprises a physical sensor that can detect an amount of lateral force applied to it by web **120** during travel. Sensor **340** can be placed upstream of steering mechanism **320**, or downstream of steering mechanism **320** as desired. In this context, the word "upstream" is used with respect to the direction of travel of web **120**.

Controller **330** comprises any system, component, or device operable to control steering mechanism **320**, based on lateral shifts detected by sensor **340**. Controller **330** can perform frequency analysis of the lateral shifts, and can direct the operations of steering mechanism **320** based on the frequency analysis. Controller **330** can be implemented, for example, as custom circuitry, as a processor executing programmed instructions stored in an associated program memory, or some combination thereof.

Steering mechanism **320** comprises any system, component, or device operable to adjust the lateral position of web **120** during printing. For example, steering mechanism **320** may comprise an Edge Position Controller (EPC) of a continuous-forms printing system, a steering frame, a web-positioning module, etc.

Illustrative details of the operation of printing system **300** will be discussed with regard to FIG. **4**. Assume, for this embodiment, that printing system **300** has started printing a print job. As a part of this process, web **120** has started traveling through printing system **300**.

FIG. **4** is a flowchart illustrating an exemplary method of accounting for lateral shifts at a web of print media. The steps of method **400** are described with reference to printing system **300** of FIG. **3**, but those skilled in the art will appreciate that method **400** may be performed in other systems. The steps of the flowcharts described herein are not all inclusive and may include other steps not shown. The steps described herein may also be performed in an alternative order.

In step **402**, sensor **340** detects lateral shifts at web **120** as web **120** travels through printing system **300**. The shifts can be measured changes in the lateral position of web **120** itself with respect to printing system **300**, or can be measured changes in a lateral force applied by web **120** to sensor **340**. The detected shifts at web **120** are provided to controller **330** for processing.

In step **404**, controller **330** identifies a frequency of the laterals shifts of the web. This may comprise interpreting input from sensor **340** in the frequency domain, and then identifying one or more frequencies that the lateral shifts regularly occur at (e.g., the peak frequencies at which the most shifting occurs, and the phases for those frequencies). In one embodiment, entire frequency spectrums of shifting can be identified by controller **330**. In a further embodiment, controller **330** applies a lowpass filter to the frequency domain data before controller **330** identifies these frequencies.

If web **120** has been continuously shifting its position laterally at identifiable frequencies, then web **120** can be predicted to continue its oscillating shifting behavior in the future. Therefore, in step **406**, controller **330** steers the web by directing steering mechanism **320** based on the identified frequency, to predictively compensate for the shifts of the web.

For example, controller **330** can generate a compensating waveform made from sinusoids that oscillate at the identified frequencies. The compensating waveform indicates the predicted future lateral shifts of web **120** during printing. In order to compensate for these shifts, controller **330** can invert the waveform (i.e., phase shift the wave form by one hundred and eighty degrees) in order to create a complementary version that should cancel out the predicted shifts.

Controller **330** can then direct steering mechanism **320** to apply shifts to web **120** based on the inverted waveform in order to cancel out the future predicted shifts of web **120**. Thus, when web **120** travels through printer **110**, web **120** remains properly positioned with respect to the printheads. Without this predictive compensation, web **120** would wobble laterally from side to side, which would cause the output from printer **110** to appear inconsistent.

Method **400** may repeat multiple times during printing, and input from sensor **340** can be used to continuously identify and compensate for changing lateral shifts in web **120**. This allows printing system **300** to prevent lateral shifts in web **120**, even when the frequency or magnitude of the shifts changes over time.

In some embodiments, sensor **340** is not positioned at the same location as steering mechanism **320**. In these embodiments, controller **330** can determine a "lag time" that it takes for the web to travel between steering mechanism **320** and sensor **340**. Controller **330** can then alter the input to steering mechanism **320** based on the lag time, in order to ensure that steering mechanism **320** compensates for the expected motions of web **120** at the correct time.

In embodiments where sensor **340** is placed downstream from steering mechanism **320**, input from sensor **340** can be used to determine whether applied corrections to the web are working as expected. Controller **330** can review input from sensor **340** after steering mechanism **320** has compensated for the lateral shifts of the web. If the input from sensor **340** shows that web **120** is still oscillating laterally, controller **330** can perform further adjustments to compensate for these oscillations.

In a further embodiment, additional sensors are used to predictively compensate for the motion of a web of print media. For example, a first sensor can be placed upstream of the steering mechanism, and a second sensor may be placed downstream of the steering mechanism. The upstream sensor can be used to measure the "natural" frequency of shifts of the web due to the normal operations of the printing system and the physical properties of the web. A controller can then direct the steering mechanism based on those identified frequencies.

The downstream sensor can measure shifts of the web that occur just before printing. If input from the downstream sensor shows that adjustments made by the steering mechanism are not sufficient, the controller may adjust the amplitude, frequency, or timing of the adjustments. For example, when multiple rollers are placed between the steering mechanism and the printer, the rollers may dampen steering applied by the steering mechanism. In such cases, the downstream sensor can detect that the web is still oscillating laterally prior to printing, and the controller can increase the amplitude of the applied steering to compensate for this issue.

EXAMPLES

In the following examples, additional processes, systems, and methods are described in the context of a printing system that predictively adjusts for oscillating lateral shifts at a web of print media.

FIG. **5**A is a block diagram illustrating a further exemplary printing system **500** that accounts for lateral shifts at a web of print media. FIG. **5**A shows a side view of printing system **500**, which includes a printer **510**, web **520**, and rollers **530** which are used to tension web **520**. Printing system **500** further includes upstream sensor **550** and downstream sensor **560**. Each of these sensors is a laser thru-beam edge position sensor that can accurately measure the lateral position of the web to within about five microns.

The sensors send lateral position data to controller **570**, which includes a processor and a memory. Controller **570** records a series of data points from sensor **550** over time for a period of several seconds. In this embodiment, since most periodic shifts of the web are expected to occur between frequencies of about 0.1 and 2 Hertz (Hz), data collection continues for multiple seconds in order to ensure that these frequencies can be accurately measured. These measured lateral shifts are illustrated in graph **600** of FIG. **6**.

Controller **570**, upon receiving a sufficient amount of data, performs a Fourier transform on the position data to acquire a frequency domain representation of the lateral shifts in the position of web **520** over time. In order to filter out noise, controller **570** applies a lowpass filter that drops out frequencies which are higher than 2 Hz. FIG. **7** is a graph **700** illustrating the filtered frequency domain representation of the lateral shifts at web **520**. Controller **570** reviews its internal memory to determine a threshold value for amplitude, and determines that threshold displacements of ten microns or more should be compensated for. Controller **570** therefore reviews the frequency domain data and determines that two frequency peaks (having a magnitude of A at 0.3 Hz, and a magnitude of B at 0.5 Hz with associated phases) cause more than the threshold level of lateral shifting. Controller **570** therefore predicts that future shifts will continue to occur at these frequencies.

To address this predicted shifting, controller **570** generates a waveform pattern that matches the identified frequencies. In this case, accounting for the detected phases of the shifts, the waveform is $A*\sin(0.3x)+B*\sin(0.5x)$. FIG. **8** is a graph **800** illustrating the generated waveform.

Once the waveform has been generated, controller **570** decides what timing to use when compensating for the predicted shifts. Controller **570** therefore reviews the current speed of the printing system, which is seven feet per second. Based on this information and a known web travel distance of seven feet from sensor **550** to Edge Position Controller (EPC) **580**, controller **570** delays the generated waveform by one second (with respect to the detected shifts) and then instructs EPC **580** to shift web **520** based on an inverted version of the waveform in order to compensate for future predicted shifts in web **520**.

A top view of EPC **580** is shown in FIG. **5**B beneath the side view of EPC **580** to illustrate how EPC **580** operates. The top view shows that EPC **580** can adjust the orientation of rollers **540**, which in turn can steer web **520** laterally as desired.

Sensor **560** can measure the lateral position of web **520** after it has been laterally repositioned by EPC **580**. Sensor **560** sends positional feedback data to controller **570**, which reviews the data to determine whether further adjustments should be performed at this time. Controller **570** may then amplify, shift, or otherwise modify the directions that it sends to EPC **580**.

Embodiments disclosed herein can take the form of software, hardware, firmware, or various combinations thereof. In one particular embodiment, software is used to direct a processing system of controller **330** to perform the various operations disclosed herein. FIG. **9** illustrates a processing system **900** operable to execute a computer readable medium embodying programmed instructions to perform desired functions in an exemplary embodiment. Processing system **900** is operable to perform the above operations by executing programmed instructions tangibly embodied on computer readable storage medium **912**. In this regard, embodiments of the invention can take the form of a computer program accessible via computer-readable medium **912** providing program code for use by a computer or any other instruction execution system. For the purposes of this description, computer readable storage medium **912** can be anything that can contain or store the program for use by the computer.

Computer readable storage medium **912** can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor device. Examples of computer readable storage medium **912** include a solid state memory, a magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk, and an optical disk. Current examples of optical disks include compact disk-read only memory (CD-ROM), compact disk-read/write (CD-R/W), and DVD.

Processing system **900**, being suitable for storing and/or executing the program code, includes at least one processor **902** coupled to program and data memory **904** through a system bus **950**. Program and data memory **904** can include local memory employed during actual execution of the program code, bulk storage, and cache memories that provide temporary storage of at least some program code and/or data in order to reduce the number of times the code and/or data are retrieved from bulk storage during execution.

Input/output or I/O devices **906** (including but not limited to keyboards, displays, pointing devices, etc.) can be coupled either directly or through intervening I/O controllers. Network adapter interfaces **908** may also be integrated with the system to enable processing system **900** to become coupled to other data processing systems or storage devices through intervening private or public networks. Modems, cable modems, IBM Channel attachments, SCSI, Fibre Channel, and Ethernet cards are just a few of the currently available types of network or host interface adapters. Display device interface **910** may be integrated with the system to interface to one or more display devices, such as printing systems and screens for presentation of data generated by processor **902**.

Although specific embodiments were described herein, the scope of the invention is not limited to those specific embodiments. The scope of the invention is defined by the following claims and any equivalents thereof.

We claim:

1. A system comprising:

a sensor operable to detect lateral shifts of a web of print media traveling through a continuous-forms printer; and

a controller operable to identify a frequency of the lateral shifts of the web, and to steer the web based on the frequency.

2. The system of claim **1**, wherein:

the controller is further operable to predict undetected shifts of the web based on the identified frequency, and to steer the web to predictively compensate for the predicted shifts of the web by generating opposed shifts at the frequency.

3. The system of claim **1**, wherein:

the controller steers the web by directing a lateral web steering mechanism; and

the controller is further operable to identify a lag time for the web to travel between the sensor and the steering mechanism, and to predictively compensate for the shifts of the web by generating opposed shifts based on the frequency and the lag time.

4. The system of claim **1**, wherein:

the controller is further operable to identify the frequency by identifying a threshold level of shift amplitude, and identifying a frequency having a shift amplitude that is greater than the threshold level.

5. The system of claim **1**, wherein:

the sensor is operable to detect lateral shifts in a position of the web with respect to the printer.

6. The system of claim **1**, wherein:

the sensor is operable to detect lateral shifts in a side-to-side tension of the web with respect to the printer.

7. The system of claim **1**, wherein:

the controller is operable to steer the web by directing a lateral web steering mechanism;

the sensor is located upstream of the steering mechanism; and

the system further comprises an additional sensor that is located downstream of the steering mechanism;

wherein the controller is further operable to receive feedback from the additional sensor, and to further direct the steering mechanism based on the feedback from the additional sensor.

8. The system of claim **1**, wherein:

the controller is further operable to apply a lowpass filter to data from the sensor prior to identifying the frequency.

9. A method comprising:

detecting lateral shifts at a web of print media traveling through a continuous-forms printer;

identifying a frequency of the lateral shifts of the web; and

steering the web based on the frequency.

10. The method of claim **9**, further comprising:

predicting undetected shifts of the web based on the identified frequency; and

steering the web to predictively compensate for the predicted shifts of the web by generating opposed shifts at the frequency.

11. The method of claim **9**, wherein:

steering the web comprises directing a lateral web steering mechanism, and the method further comprises:

identifying a lag time for the web to travel between a sensor detecting the shifts and the steering mechanism; and

predictively compensating for the shifts of the web by generating opposed shifts based on the frequency and the lag time.

12. The method of claim **9**, further comprising:

identifying the frequency by:

identifying a threshold level of shift amplitude; and

identifying a frequency having a shift amplitude that is greater than the threshold level.

13. The method of claim **9**, further comprising:

detecting lateral shifts in a position of the web with respect to the printer.

14. The method of claim **9**, further comprising:

detecting lateral shifts in a side-to-side tension of the web with respect to the printer.

15. The method of claim **9**, wherein:

steering the web comprises directing a lateral web steering mechanism;

detecting the lateral shifts is performed by a sensor located upstream of the steering mechanism; and

the method further comprises:

receiving feedback from an additional sensor downstream of the steering mechanism; and

directing the steering mechanism based on the feedback from the additional sensor.

16. The method of claim **9**, further comprising:

applying a lowpass filter to the detected shifts prior to identifying the frequency.

17. A non-transitory computer readable medium embodying programmed instructions which, when executed by a processor, are operable for performing a method comprising:

detecting lateral shifts at a web of print media traveling through a continuous-forms printer;

identifying a frequency of the lateral shifts of the web; and

steering the web based on the frequency.

18. The medium of claim **17**, wherein the method further comprises:

predicting undetected shifts of the web based on the identified frequency;

steering the web to predictively compensate for the predicted shifts of the web by generating opposed shifts at the frequency.

19. The medium of claim **17**, wherein:

steering the web comprises directing a lateral web steering mechanism, and the method further comprises:

identifying a lag time for the web to travel between a sensor detecting the shifts and the steering mechanism; and

predictively compensating for the shifts of the web by generating opposed shifts based on the frequency and the lag time.

20. The medium of claim **17**, wherein the method further comprises:

identifying the frequency by:

identifying a threshold level of shift amplitude; and

identifying a frequency having a shift amplitude that is greater than the threshold level.

21. The medium of claim **17**, wherein the method further comprises:

detecting lateral shifts in a position of the web with respect to the printer.

22. The medium of claim **17**, wherein the method further comprises:

detecting lateral shifts in a side-to-side tension of the web with respect to the printer.

23. The medium of claim **17**, wherein:

steering the web comprises directing a lateral web steering mechanism;

detecting the lateral shifts is performed by a sensor located upstream of the steering mechanism; and

the method further comprises:

receiving feedback from an additional sensor downstream of the steering mechanism; and

directing the steering mechanism based on the feedback from the additional sensor.

24. The medium of claim **17**, wherein the method further comprises:

applying a lowpass filter to the detected shifts prior to identifying the frequency.

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